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A Research on the Extraction and Interpretation of Power Line Communication Noise Pattern Using Genetic Algorithm

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Abstract. A PLC is more sensitive in noise than other wired communication system that is cable, DSL, and optical LAN. Therefore it considered as a crucial point in commercialization of PLC. For the commercialization of PLC, noise reduction and cancelation technique are needed. Therefore, it is definitely required to analyze and interpret the effects and types of the noise, exactly. The purpose of this work is to separate and extract the various noise of power line from data signals.

1. Introduction

The AMR-based AMI system uses PLC as a main communication technology to build Smart Grid. Despite these advantages, PLC is quite weak in the inflow noise of power lines because it uses deteriorated power lines, low-frequency band(1 ~ 30MHz) compared to other wired communication , and same frequency band for both upward and downward communication.[2] The weakness in noise decreases its stability and reliability and it is the significant barrier of PLC diffusion. For this reason, the research for minimizing and eliminating the critical effect of noise has been driven because it decreases performance of PLC. This paper introduces the study for recognizing and classifying the PLC noise pattern to minimize the critical effect of PLC noise with GA(Genetic Algorithm).

2. The PLC noise of AMR

In Korea, KEPCO(Korea Electric Power Corporation) consortium is mainly establishing and providing the AMR-based AMI system and the related service actively. For several decades, we spurring the development of new system to perform the remote meter reading for most consumers using low voltage. The bi-directional PLC technology is used between DCU and a smart meter, between DCU and gateway. It uses the power line inside of consumer's residence in the configuration of network, therefore it is quite weak in the noise caused by deteriorated power lines and electronic products. There are several kinds of noise such as ① colored background noise; ② narrow band noise; ③ periodic impulse noise synchronous with power frequency; ④ non-periodic impulse noise; ⑤ burst noise.[3] Of these, we simulated pattern recognition to discriminate the color noise occurs in a specific frequency band. The configuration of AMR operated currently is shown in Fig. 1.

3. GA for extracting PLC noise characteristic pattern

Recently, the large-scale optimization problems with complex constraints among various engineering applications are very difficult to get optimal solutions with general mathematical programs and a combination of optimization algorithm within a short computation time. Therefore, GA which is one of the evolutionary algorithms is used as the primary mechanism for solving these problems within a reasonable computation time.[4] GA finds a candidate solution with selection, crossover and mutation for the problem and it also finds an optimal solution by transforming population which is a set of organisms into new population repeatedly. These are basic operations of the GA to define a mechanism and improve its efficiency. [5] The basic algorithm flow chart is shown in Fig. 2.

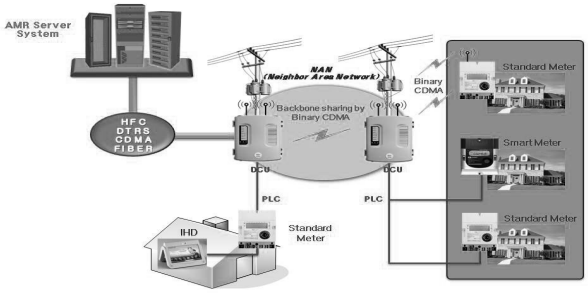


Fig. 1. The PLC configuration based on the AMR

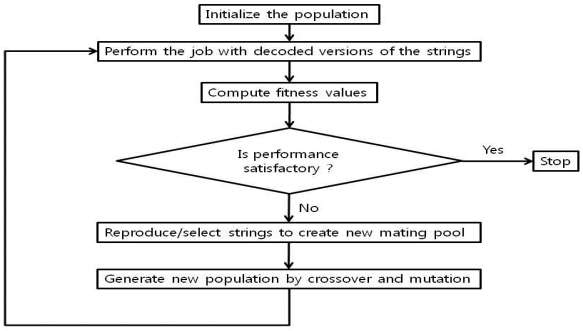


Fig. 2. Basic flow chart of a GA

We implemented the algorithm based on the basic GA that will be applied to the PLC noise pattern recognition. (Algorithm. 1) The arithmetic expressions applied to the Algorithm. 1 are defined as follows Eq. 1 to Eq. 6

Algorithm 1. A Genetic Algorithm with proposed pattern recognition

```
procedure GA()
    initialize(Population);
    evaluate(Population);
    while not (terminal condition satisfied) do
        MatingPool = reproduce(Population);
        MutationPool = crossover(MatingPool);
        Population = mutation(MutationPool);
        evaluate(Population);
    end while
end procedure
```

Initial population : $v_i = [x_1\ x_2\ x_3 \cdots x_{30}],\ i = 50$ (1)

Evaluation : $Eval(v_i) = f(x^i),\ i = 1,\ 2, \cdots,\ 50)$ (2)

$$F = \sum_{i=1}^{50} Eval(v_i)$$

Select : $$p_i = \frac{Eval(v_i)}{F},\ i = 1,\ 2, \cdots,\ 50 \quad (3)$$

$$q_i = \sum_{j=1}^{i} p_j,\ i = 1,\ 2, \cdots,\ 50$$

Crossover : $$p_c = \frac{p_{ct}}{(pop\_size)} = \frac{35}{50} = 0.7 \quad (4)$$

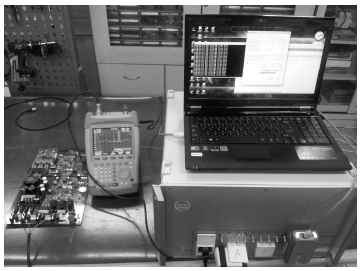
where, p_c is the probability of breeding, p_{ct} is the number of genes that is the breeding target.

Mutation : $$p_m = \frac{p_{mt}}{(pop\_size)} = \frac{5}{50} = 0.1 \quad (5)$$

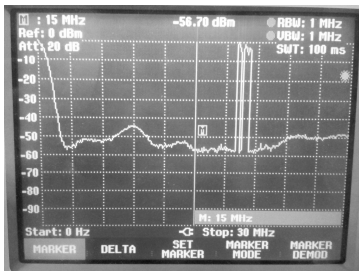
where, p_m is the probability of mutation, p_{mt} is the number of genes that is the mutation target

End : $$STOP > G,\ G = 100 \quad (6)$$

We established the PLC network for comparing simulation data with the actual PLC noise pattern. (Fig. 3(a)) The DCU at the left bottom is connected to the PLC modem and spectrum analyzer at the right bottom by power line. Also, the PLC modem is connected to the laptop by RJ45 port for data transmission. The obtained frequency image is shown in Fig. 3(b)



(a) The PLC network for experiment



(b) The PLC spectrum pattern

Fig. 3. Lab environment and frequency pattern image

The remote PLC modem connected to the DCU transmits RF signal strength to a remote server by scanning 1 ~ 30MHz frequency band per 1MHz regularly to provide the digital data of specific RF signal strength to the simulator for pattern recognition. The simulator on a remote server predicts continuous frequency waveform by performing GA with the data and it discriminates the particular signal and color noise.

4. Performance and result of the noise pattern recognition

We applied GA for pattern recognition of the PLC color noise. We predicted and recognized the overall pattern with dispersed data of a particular frequency by measuring the entire PLC communication frequency band. As a result, we were approximately able to estimate the pattern of entire frequency and isolate the color noise occurred at a specific frequency from a signal. The approximately predicted graph is shown in Fig. 4. The trianlge shape means noise, circle shape means signal in the Fig. 4. We drawed a change in the pattern by increasing population size and generation as shown in Fig. 5. As a result, we make sure that the overall pattern is remained constantly but the slight change.

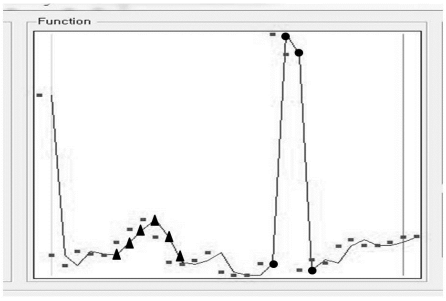
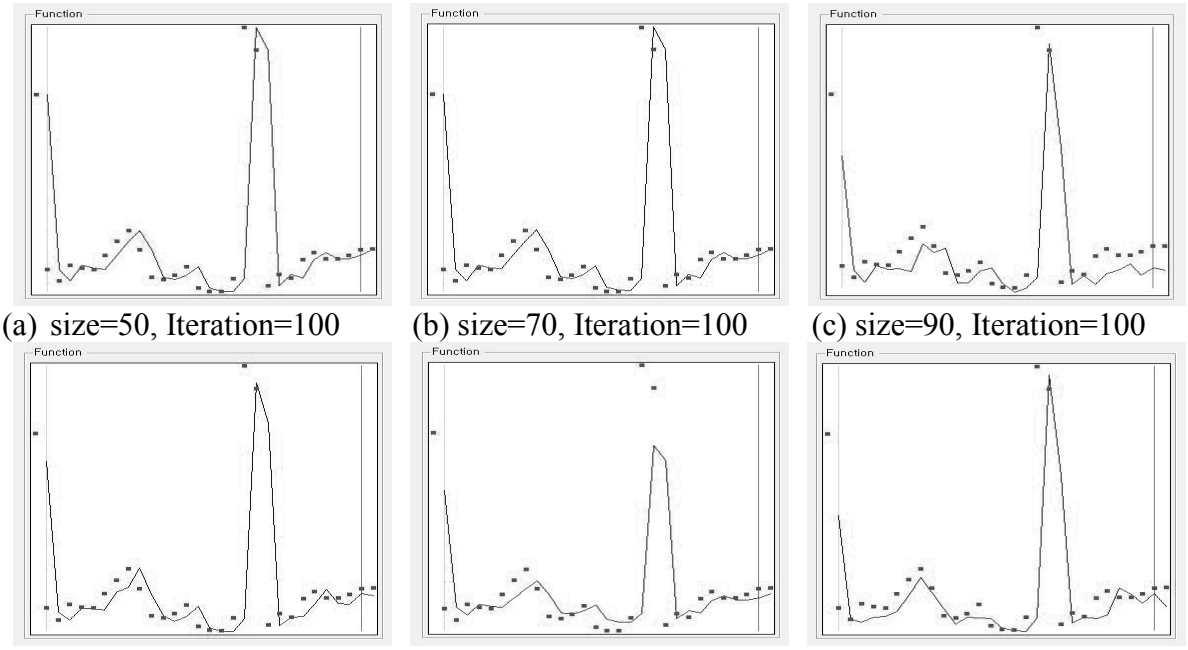


Fig. 4 The characteristic pattern recognition of the PLC after applying algorithm.

It is essential to ensure quality and reliability of the PLC communication which has come to the main problem of the AMR-based AMI system. Consequently, we studied the noise pattern recognition as the pre-required base technology for applying other technology to reduce and eliminate the noise of PLC. We simulated only for the color noise occurs in a specific frequency. However, the different types of noise can occur in PLC at the same time and it causes complex problems. Therefore, the research for the white noise across the whole spectrum and other types of noise is necessary in the future. The H/W processor for implementing the S/W simulation should be developed to recognize the pattern during unstable communication status due to noise and also take the measures for it in real-time.[7, 8, 9]



(a) size=50, Iteration=100 (b) size=70, Iteration=100 (c) size=90, Iteration=100

(d) size=50, Iteration=1000 (e) size=70, Iteration=1000 (f) size=90, Iteration=1000

Fig. 5 Simulated pattern by changing population size and generation step

5. Conclusion

In this paper, we applied GA for color noise cancelation and noise analysis of the transmitted signal. The addictive noise in transmitted signal is efficiently separated with GA. The analyzed noise information can be used for noise cancelation in power line communication. With this approach, we can remove the noise problems in PLC and improve the stability of system and the reliability of received data. We clarify that we developed the simulator mentioned in this paper by modifying the base program code following "GNU General Public License, version3 (GPL-3.0)". [10]

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